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Technical Lesson 50

GREBE -- BATTERY AND A.C. RECEIVERS

The Grebe Synchrophase set is a representative example of a five tube tuned radio-frequency receiver. It consists of two stages of tuned radio-frequency amplification, a non-regenerative detector, and two stages of transformer coupled audio amplification. The diagrammatic wiring lay out of the receiver system is shown in Figure 1.

The features of a single-dial controlled receiver are maintained and, at the same time, some of the flexibility of multiple control is possible. The tuning elements consist of three variable condensers each adjustable by means of a horizontally mounted dial on the front of the panel. All of the dials may be controlled from the master, or center dial, or each radio-frequency circuit may be individually tuned to increase selectivity by simply releasing thumb nuts provided for that purpose. Equal spacing of broadcasting stations over the dial scale is accomplished by the use of scientifically shaped condenser plates. Condensers of this type are known as straight line frequency (abbreviated, S-L-F) condensers. When tuning with condensers of this kind it will be found that the spreading out of stations uniformly prevents of crowding of stations along the lower end of the tuning range; i.e. at the short wave or high frequency end of the broadcast spectrum.

The front panel view, illustrated in Figure 2, shows the operating controls. The left hand dial tunes the first radio-frequency circuit, the middle or master dial the second radio-frequency circuit, and the right hand dial the detector stage. The volume control is for the purpose of regulating the strength of the signal after it has been accurately tuned in. It consists of a variable resistance placed in the filament circuit of the first and second radio-frequency tubes, thus permitting a continuous variation of filament voltage supplied to these tubes. This control also serves as an "ON" and "OFF" switch which automatically controls the filament voltage of the detector and two audio frequency amplifying tubes. The control of volume by detuning the radio frequency circuits after a signal is received is not recommended because the quality of tone will be altered. A small dial light connected across the filament circuit illuminates the dial numbers on the center control and also serves as a pilot lamp which is useful as a visual precaution against leaving the filaments in operation unnecessarily.

A control knob, marked "TONE COLOR", is attached to a switching arrangement which allows various capacities to be selected from a bank of condensers shunted across the secondary winding of the second audio transformer. The internal wiring diagram of the receiver in Figure 3 clearly indicates the relation of this condenser bank to the input or grid circuit of the last audio amplifier, marked on the drawing 2nd A.F. The purpose

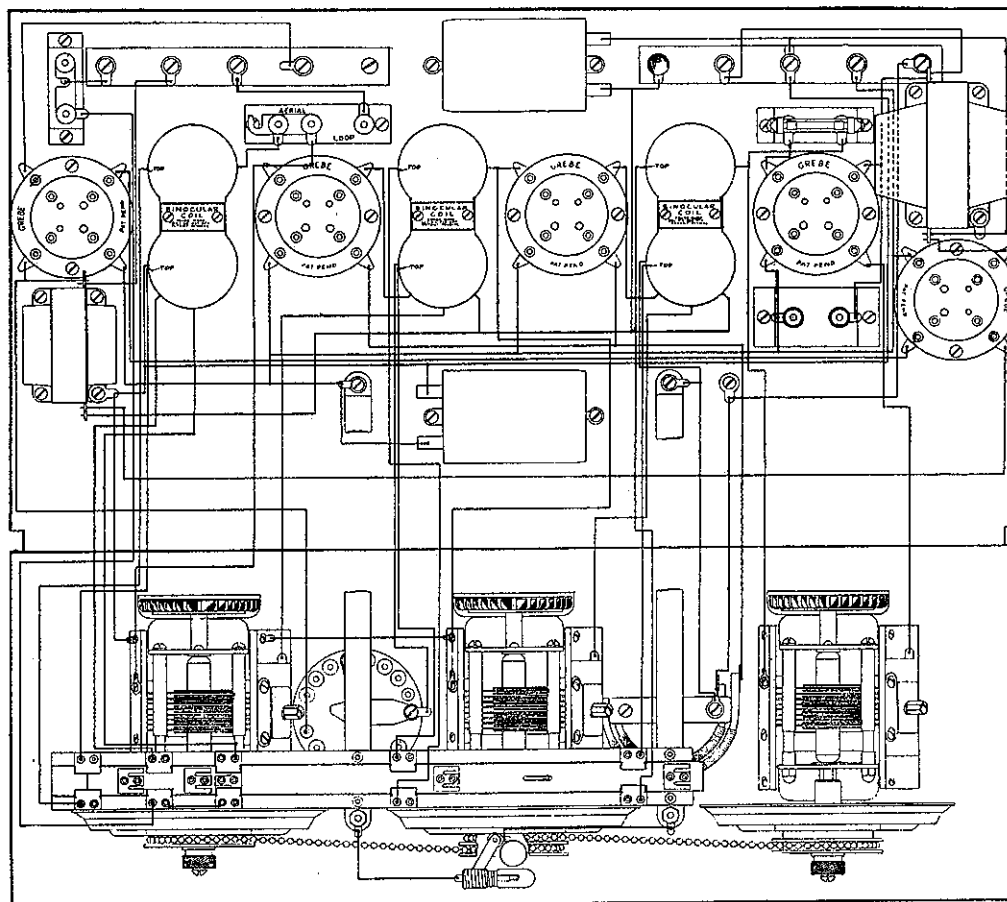


Figure 1

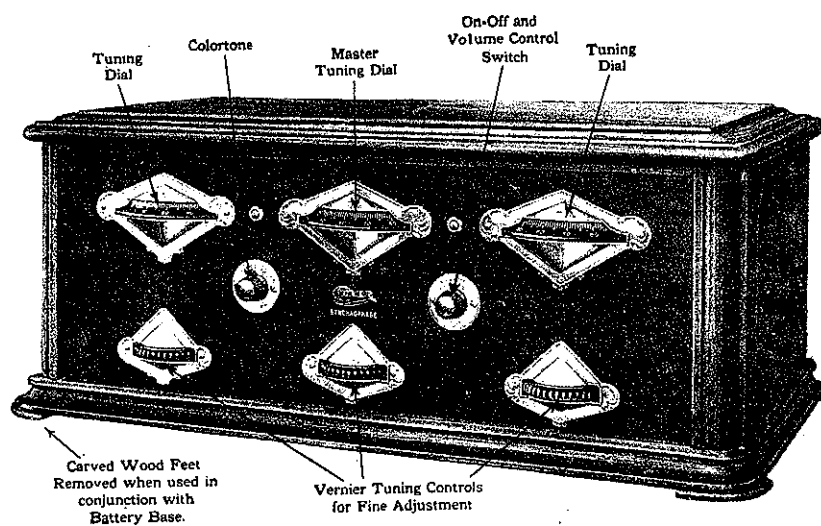


Figure 2

of this adjustment of capacity is to permit high or low audio frequencies to be either accentuated or suppressed, thus making it possible to alter the timbre or depth of the voice or instrument of a broadcast rendition.

The Synchrophase circuit is especially designed and balanced to operate with UX201-A or C301-A type vacuum tubes. These tubes are of the 5-volt, 0.25-ampere variety. An unbalanced or oscillating condition may be experienced whenever tubes are used having internal characteristics unsuited to the particular balance adjustments of the radio frequency stages of the receiver. Although the 201-A type tube is known as an all-purpose or general utility tube and may be used in all stages of this particular receiver, yet it will be found that when employed in the last audio stage the amount of signal voltage which the grid can handle without overloading is somewhat limited. That is, the limit of undistorted power is low. The 201-A will prove adequate for an ordinary sized room where large volume is not a requirement and when operating in conjunction with a loudspeaker having favorable characteristics. However, modern radio reception most generally demands a large output of undistorted volume and to satisfy this requirement a UX-112 or CX-112 type power tube can be used in the last audio frequency stage. An improvement in tone quality and volume may not be noticed by merely substituting the 112 power tube for the ordinary 201-A. The characteristics of the 112 power tube make a high "B" voltage necessary to obtain maximum results. The potential applied to the plate is increased by means of an additional $22\frac{1}{2}$ or 45 volt "B" battery provided only 90 volts are being used. The "C" voltage should always be properly adjusted for any variations in "B" supply in order that the tube will operate safely below the distortion point limit; i.e., so that perfect reproduction and clarity may be expected at all times even on loud passages of music. It is always advisable to adhere to the manufacturer's rating, never exceeding the maximum values that are specified for the various tubes.

The operating characteristics of the power tube make it essential to keep the proper relation between the "C" bias voltage and the "B" plate voltage. A plate voltage of 135 or higher is recommended for the 112 tube, the maximum allowed being 157 volts. Failure to provide the correct "C" bias potential will not only be a likely cause of distortion but may seriously lower the available output power supplied to the speaker. It should be borne in mind that vacuum tubes of similar type often vary in their general characteristics. When unsatisfactory operation of the receiver is experienced and several tubes of a similar type, such as the 201-A stage, are used in various circuits, with the exception of the final audio or output stage, it is suggested that the tubes be interchanged in different sockets until best results are obtained. It will be found that certain tubes are sometimes more particularly suited for radio-frequency than for audio frequency amplification.

In order to prevent damage to the delicate filament wire in the tubes, and to coils which form part of the plate circuits, the filament rheostat should be turned off before removing or inserting tubes in the sockets.

While we are discussing the relative performances of different types of amplifier tubes it seems advisable at the same time to give a brief explanation of the theory involved in the use of proper amounts of fixed grid and

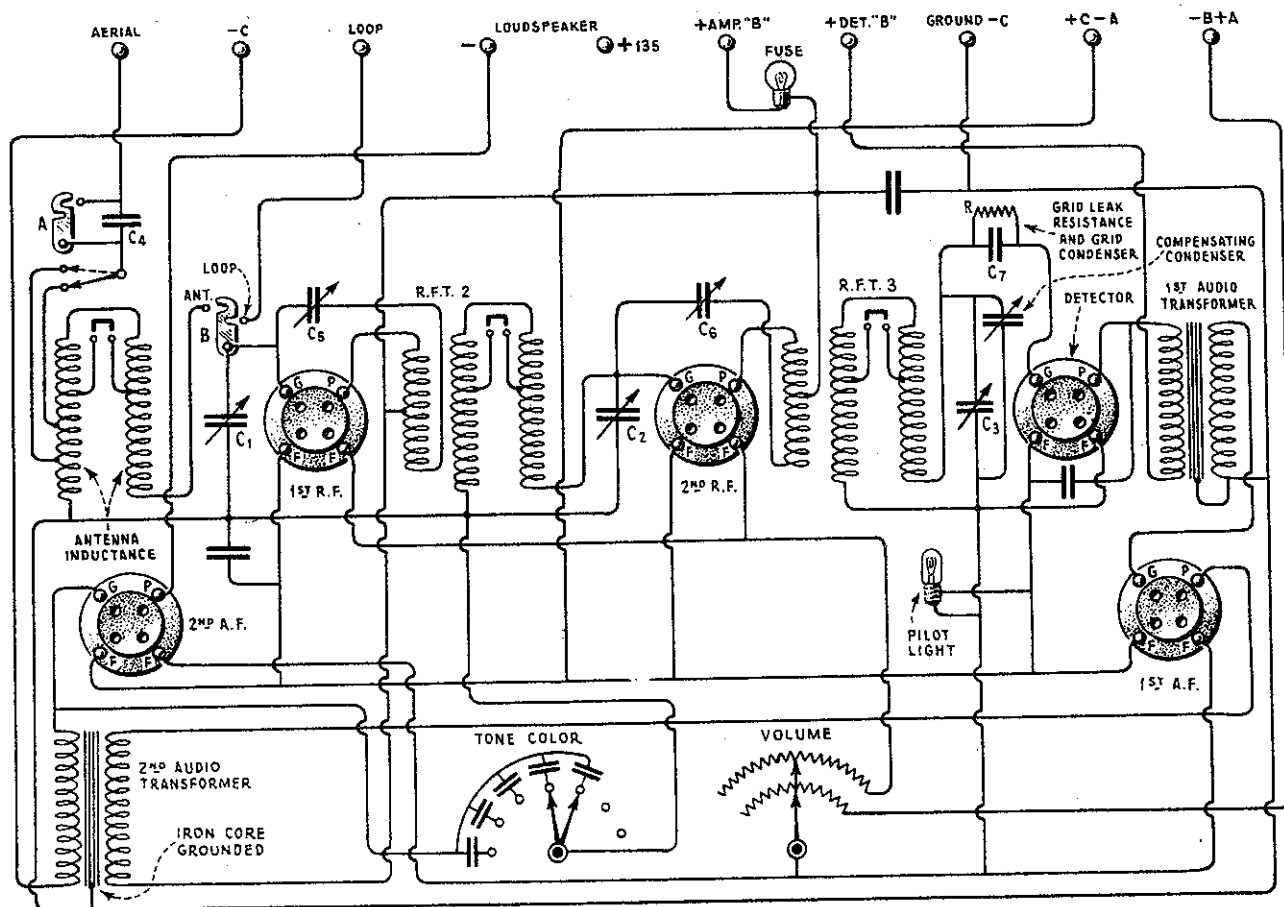


Figure 3

plate voltages. When a tube is operating as an amplifier and the input signal energy is too great, or the voltages supplied by the "B" and "C" batteries are incorrectly adjusted, the normal working point on the curve representing the static characteristic of the tube will go beyond the limits of the linear or straight portion, and distortion will result. There are two improper effects to be noticed, one when the "C" voltage is too low, and the other when too high.

In the case of insufficient "C" bias a large signal input voltage may actually overcome the "C" voltage, and it follows that the grid potential will swing to the positive side thus introducing distortion in the speaker. This action may be accounted for by the fact that whenever the grid is allowed to become positive it attracts an excessive number of the emitted electrons coming from the filament; these electrons would otherwise ordinarily reach the plate. Electrons absorbed by the grid means, when expressed in terms of current flow, that the grid draws a small amount of current which causes a considerable drop in the input voltage only on the positive alternations. On the other hand, when too much "C" bias voltage is used, the grid electrode becomes charged with a heavy negative electric potential causing it to repel large quantities of emitted electrons. Consequently, fewer electrons reach the plate than would be the case when

operating the grid under normal conditions. A reduction in electron flow to the plate is equivalent of stating that the plate current is lowered to an amount less than normal, hence, the working characteristic of the amplifier is forced down from the straight portion of the curve to the lower bend. Distortion is then set up, producing extraneous sounds of high frequency which are not included in the original broadcast program.

The possibility of distortion being produced in a vacuum tube amplifier can only be prevented by using correct grid and plate voltages, as mentioned heretofore, thus operating the tube so that all plate current variations are proportional to the alternating voltage delivered to the grid from the secondary of the audio transformer. When this condition obtains it indicates that a normal value of plate current flows in the output of the tube because the tube is being operated on the straight line of its characteristic curve. Now, when the grid receives the signal energy as an alternating voltage it will cause the plate current to rise during a positive alternation and fall during a negative alternation, all variations being proportional to the input signal voltage. This results in a fluctuation of plate current which carries the true reproduction of the original speech or music.

Let us now consider the tuning system and synchronizing the circuits of the receiver. Tandem tuning of condensers, generally known as single-control, is used to decrease the number of separate controls. There are several methods which will permit the ganging of tuning condensers. An examination of the photograph of the interior arrangement of the set clearly shows the chain and pulley system used to link the dials. Here the center dial controlling tuned circuit No. 2 (the second stage of radio-frequency amplification) is equipped with two pulleys which are rigidly attached and move with it, thus imparting movement to the chains coupling the other two tuned circuits. The tuned circuit No. 1 is coupled to the antenna system, and No. 3 to the detector.

If satisfactory results are to be obtained the output and input characteristics of each tuned radio-frequency stage should be alike. The wiring diagram shows how the tuned circuit of one tube works into the grid tuned circuit of the following tube. Although the coils and condensers in each stage may be designed with similar characteristics provision is made to permit a flexible control in the event that for any reason it is found that one of the radio-frequency stages will not tune in exact step with the other two stages. This is accomplished in certain types of receivers by employing some compensating device. This device in some cases consists of a variable condenser, one of low capacity, called a midget condenser, shunted across the main tuning condenser, the combination requiring an additional tuning control. The equalizing of the tuned circuits in the Synchrophase receiver, however, is made possible through a mechanical adjustment of thumb-nuts, by which the right and left-hand dials may be released, thus permitting all the dials to be rotated independently. Or, the three radio-frequency circuits may be tuned to exact resonance by allowing sufficient slack in the left-hand chain to move dial No. 1 (controlling the first radio-frequency stage) about three degrees without moving center dial No. 2 (the second radio frequency stage). The chain coupling the other dial No. 3 (the third radio-frequency stage) to the center dial

should be given sufficient slack amounting to a movement of about two degrees. Slight differences in the settings of the dials may be corrected in this way. The broadcasting of local stations should be heard readily by turning the main or center dial slowly, thus synchronizing all three tuned circuits simultaneously until resonance is established with the desired signal frequency. If the reception requires clearing up, a fine tuning adjustment can be effected by slightly moving to the right or left the vernier wheels located directly under the tuning dials.

The dimensions of a particular antenna system will influence the setting of the left-hand dial, since the variable condenser attached to this dial regulates the frequency of the input circuit. The effect of the antenna upon this first tuned circuit may be compensated and the circuit brought into exact resonance at any of the wavelengths by utilizing the individual dial control features previously explained.

A study of the circuit diagram will show that the receiver may be adapted to practical operation on various sizes of antennas, or loop antenna, according to the demands of location or installation limitations. Two link switches marked A and B are supplied for this purpose. The drawing shows link A disconnected which places a small fixed condenser in series with the antenna circuit. A series condenser decreases the capacity of the antenna system and therefore lowers its fundamental wavelength. Consequently, the condenser should be connected in only when an oversized antenna is used or when additional selectivity is required. When link A is closed, it acts as a short circuiting jumper across the series condenser, thus increasing the electrical length of the antenna, this adjustment being suggested whenever a 125 foot antenna is used or when additional volume is desired. It is essential that this link be closed when employing loop reception. The link is located on the instrument board directly to the rear of the first radio-frequency tube.

An outdoor antenna consisting of a single copper wire not exceeding 125 feet in length, including the lead-in, will usually bring in signals with greater volume and greater range of reception than antennas of shorter lengths or of the loop type. If an outdoor antenna of the size suggested above makes selectivity difficult to obtain it will be necessary to shorten it to about sixty or seventy-five feet in length. A loop inherently possesses directional characteristics which increases the selectivity of the receiver and often times proves advantageous when close to broadcasting stations transmitting on considerable power. Although a loop does not pick up signal energy from a passing electromagnetic wave comparable in strength to an outdoor antenna, or a suitably installed indoor antenna yet if the reception in general in a particular location is satisfactory it is possible to obtain efficient results providing the loop is one of average size and wound with the proper number of turns. Link B is provided for the purpose of cutting out the antenna coupling coil and connecting directly to a loop. The substitution of a loop for the antenna coil will cause a large variation in the tuning adjustments of the first condenser dial from those of the other two dials. This is a natural result to expect since the constants of the first or input radio-frequency circuit will be altered due to the fact that a loop has a wide difference in distributed and extraneous capacity from that of the coil and antenna system

which it replaced. The tuned circuits may be perfectly synchronized by releasing the coupling chains and adjusting the dials individually.

The following specifications give approximately the overall dimensions of loops of various sizes, equipped with intermediate taps to allow the use of fewer turns on the lower wavelengths.

Size of Loop Measured at Average Turn.	Total Turns	Tap at Turn No.	Tap at Turn No.
15 inches	24	12	6
18 "	20	10	5
24 "	15	7	3
32 "	12	6	3

It should be remembered that reception will not be satisfactory when a set is operated from a loop in a building constructed of wire mesh or metal lath, or iron or steel beams, or where large amounts of metal reinforcement are used. The metal acts to absorb the energy in a radio wave thus preventing all or part of it from reaching the loop and in this case the directional properties of the loop are destroyed. Under such conditions it is usually found necessary to point the loop toward the iron construction in order to strengthen the reception and not necessarily toward the actual direction of the station whose signals are to be received. This peculiar condition is due to metal masses picking up or absorbing energy similar to an antenna conductor and reradiating it to the loop. A loop should be used only when there is no other alternative in regard to the installation of an antenna.

The detector and radio-frequency stages are tuned by a special type "field-less" coil, known as the "binocular" coil, which serves to remove the tendency toward oscillation in the amplifier circuit. Absence of an external magnetic field around these inductances is due to the method of balancing the component parts. The secondary inductance of this specially designed transformer consists of two separate coils connected in series but with their turns wound in opposite directions upon cylindrical tubing and mounted side by side, as shown in Figure 4. The primary, or plate coil, is placed within one of the secondary sections and cannot be seen in the illustration.

Observe from the diagram in Figure 3 that the primaries of the second and third radio transformers, marked R.F.T.2 and R.F.T.3, are tapped in the center and from each respective tap a lead connects to the "B" battery supplying d-c plate excitation to the tube associated with the transformer, whereas the other leads are attached respectively to two small adjustable condensers, C-5 and C-6, which are provided for the purpose of balancing or neutralizing the inter-electrode capacities of the radio amplifier tubes. A more detailed explanation of these condensers is given in subsequent paragraphs. These special designed coils will not respond to outside influence, hence the only route for the introduction of signal impulses into the circuits of the receiver is through the antenna system. Selective tuning is only possible when the internal elements of a set cannot directly pick up a strong broadcast signal.



Figure 4

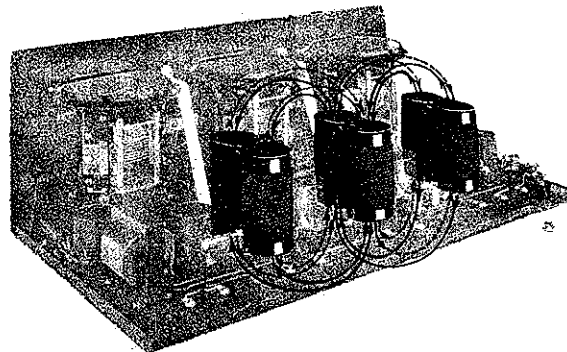


Figure 5

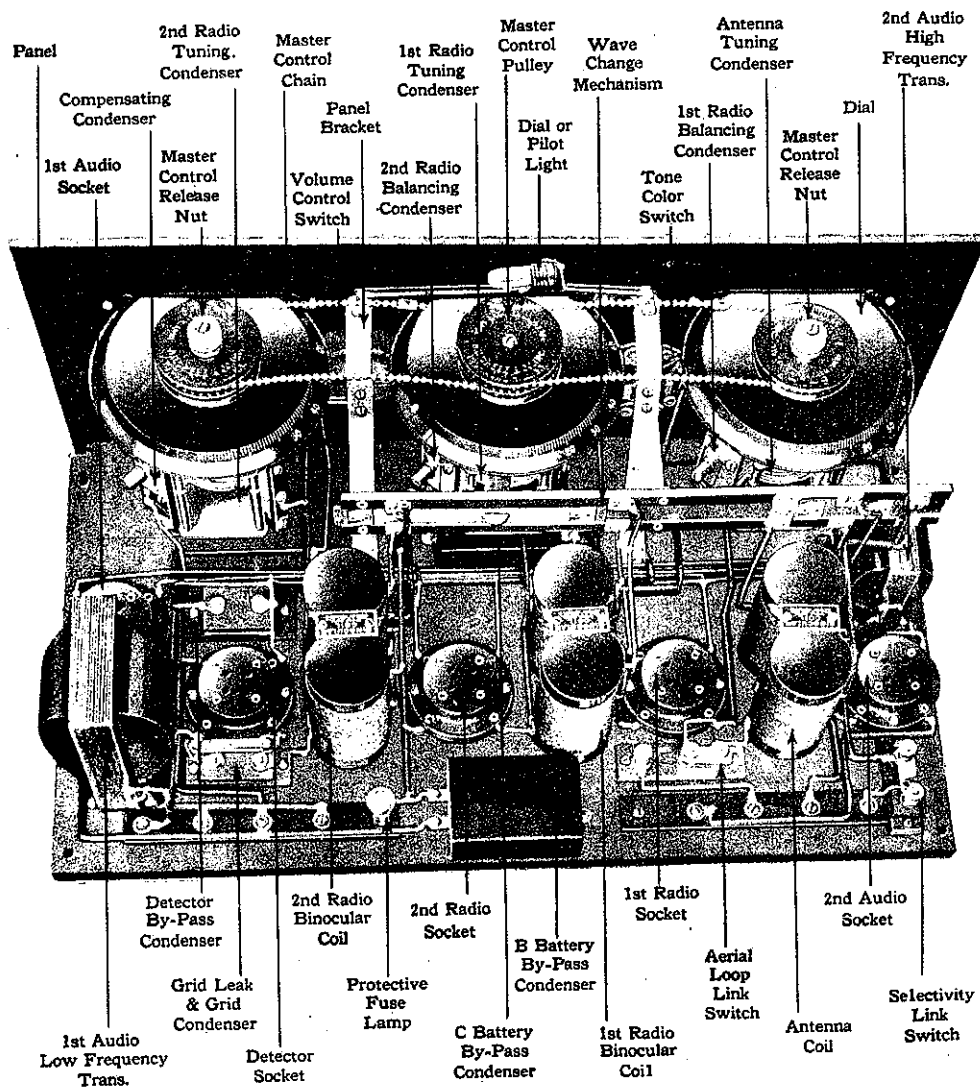


Figure 6

It stands to reason that the tuning of a broadcast receiver must be sufficiently sharp to discriminate between stations operating on different wavelengths to produce clear reception of the desired station. And yet, it is well known that the tuned circuits should be broad enough to take in all the audio frequencies transmitted by the desired station, which includes for all practical purposes a band ten-kilocycles wide, and exclude everything outside it. This point in regard to the degree of selectivity realized in the practical tuning of radio-frequency circuits may indeed be emphasized. Elimination of interference from unwanted stations working on neighboring wavelengths can be expected only when the signal energy feeds from the antenna system to the first tuned radio-frequency stage (composed of the binocular coil marked "antenna inductance" and the variable condenser C1) and thence through the successive tuned stages controlled by condensers C2 and C3. In this manner the pulsating electrical energy conveying the chosen signal will be amplified through each stage and undesired ones reduced in strength. The gain in amplification per stage determines the amount of signal voltage delivered to the grid of the detector tube.

Mounting fieldless coils with their center axes at a particular angle with one another is unnecessary as the illustration in Figure 5 clearly indicates. The position of the three coils is such that their center axes all lie in the same plane. The illustration shows the paths taken by some of the magnetic lines of force which establish themselves around the second or middle binocular coil when current flows therein. It is easy to understand that a limited number of lines will reach the two outer coils. A close examination of the dotted lines and arrows designating the direction of the magnetic lines will reveal that in the two outer transformers the fields from one-half of the second transformer are counteracted by the fields from the other half. The two magnetic fields are equal in magnitude and opposed in direction which actually results in no field existing at all, and therefore magnetic coupling between the transformers is eliminated. Moreover, it could be shown by drawing additional lines of force originating from the other transformers, that these fields would be interposed in a similar manner, with the same results; i.e., neutralization or cancellation of magnetic effects in the space separating the radio-frequency stages.

A feature of the Syncrophase receiver discussed in the text of this lesson is the low-wave extension. The mechanical arrangement of this device is shown in the complete receiver illustrated in Figure 6, where all of the component parts are labelled. A studied comparison of this layout should be made with the diagrammatical wiring diagram held before you in order that you may not only obtain practice in the reading of diagrams but become familiar with the actual arrangement of the elements forming the various circuits.

By providing two ranges of tuning the receiver will perform with full efficiency over the entire band of broadcast wavelengths from 550 to 200 meters, or, in terms of frequency, from 550 to 1500-kilocycles. Although the S-L-F condensers will permit practical tuning without apparent crowding of stations at the lower end (short wave or high frequency) of the dials yet the electrical design of radio-frequency circuits do not permit of maximum efficiency for the complete range. The two ranges of tuning

practically gives the equivalent of two sets, each one capable of efficiently covering its own frequency band.

Ordinary adjustments of the dials tunes the radio-frequency circuits in the "high range", from 550 to 240-meters, or 550 to 1250-kilocycles. By rotating the master (or center) dial attached to condenser C2 as far as possible past zero, the range is automatically shifted to the "low-range" to receive stations transmitting between 360 and 150-meters, or 830 to 2,000 kilocycles. The tuned circuits of the receiver are again returned to the "high range" when the master control dial is rotated past division mark 100 on the scale.

The mechanical operation of the high and low-wave range is accomplished by the movement of a slide switch (located directly in front of the radio-frequency coils) when the master dial is moved beyond zero or beyond the

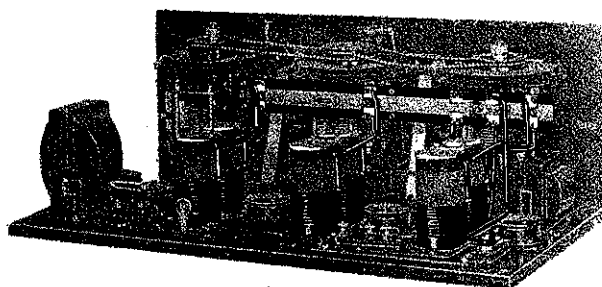


Figure 7

hundredth division as we have just mentioned. When turning the master dial the observer will notice a slight inertia of its movement as the zero mark is approached. If you could examine the mechanism it would be apparent that a metal lever extending out from under the master dial would move in the direction in which the dial might be rotated, thus actuating the wave-changing switch throwing it far enough to close all connections. Briefly, the inductance of the binocular coils is reduced and the antenna coupling coil is also changed by the tap arrangement when this switch is brought into play.

It will be noticed in the view of Figure 7 that the switch is thrown to the left and the two halves of each binocular coil are connected together at about their mid-points. In effect the shunted coil sections form them into smaller binocular coils consisting of one-half the number of turns. In order to prevent, as far as possible, any losses that might occur in the active sections of each coil, owing to the presence of the unused upper turns, that short-circuiting is actually made through a very low resistance and short leads. Furthermore, the change in the inductance of the antenna coil by cutting out from fifteen to ten turns will be found to be advantageous for the following reasons. The first or antenna tuning condenser C1 can be kept in alignment with condensers C2 and C3 by maintaining the antenna coupling inductance in its proper relation for low waves. The decrease in the number of turns used in this coil has the effect of reducing antenna coupling, resulting in greater selectivity. Also, the volume from the loudspeaker will be slightly reduced as compared with the

results obtainable when using the "high range" but this decrease in volume is not serious. Remember, that in the operation of all tuned circuits a slight gain in selectivity can be obtained with some sacrifice in sensitivity, and the converse of this is also true.

The low-range adjustment finds its principal usefulness whenever a station located at about 40 on the dial is difficult to separate from interfering stations. If a comparative dial setting was approximated for the entire range of the receiver it would indicate, taking, for example a specific location on the dial, that a broadcast station tuned in at 38 on the high-range would be heard at about 78 on the low-range. The two ranges overlap from 240 to 350 meters and stations transmitting in this band will generally be received with greater selectivity on the low-range and greater sensitivity on the high-range. This switch should be examined occasionally to prevent any possibility of the springs contacts making poor electrical contact.

Now, let us consider how we are to determine when the balancing condensers C5 and C6, referred to in the early part of this lesson, require readjustment. Before proceeding further we might explain that a small balancing condenser associated with a certain amount of inductance is shunted across the grid and plate electrodes of a radio-frequency amplifier tube in order to form what is known as a bridge circuit. When the bridge is balanced by correctly adjusting the capacity of the small condenser the electrostatic coupling between the grid and plate is nullified or neutralized. The coupling effect referred to here is due to the fact that whenever the grid and plate are charged electrically the space between possesses all of the characteristics of the dielectric of a condenser. In other words, the tube elements and the space separating them are in effect a small condenser having a definite amount of capacity. Consequently, if this capacity effect in the tube can be neutralized; that is, made as though it did not exist at all, the tube will not then act in conjunction with the coils and capacities of the radio circuits to promote the generation of unwanted radio-frequency oscillations. If we assume that such uncontrolled oscillations are allowed to be produced they are easily detectable by the following well known indications. If a distinct whistle or howl is heard when all of the tuned radio-frequency circuits are exactly synchronized by means of the dials, or a blotting out of a broadcast station is noticed when tuning in a distant or local station this is almost positive evidence that the circuits are oscillating or in an unbalanced state. One can only be sure of this deduction, however, if it is definitely known that the whistle is not emanating from a local oscillating receiver, or due perhaps to the phenomenon known as heterodyning. In the latter case the audible whistle is a resultant energy produced through the combining of radio oscillations picked up by the receiving antenna from two stations transmitting simultaneously at frequencies within a fractional difference of one another. There is no cure for the annoyance which a whistle of this kind causes when listening to a broadcast program. The remedy lies entirely in the hands of the Radio Commission at Washington who have recognized this condition and are re-allocating the assigned frequencies of many stations to prevent further undesirable interaction of radio waves.

The following procedure is suggested for changing the balance adjustment.

The receiver must be placed in its usual normal operating condition before altering the capacities of the balancing condensers. The antenna and ground connections should be complete. Tubes known to be perfect by previous test should be inserted in the sockets with the filament voltage adjusted until normal current is supplied, also, the "A", "B" and "C" batteries and loudspeaker should be properly connected. The voltage of all batteries should be checked and if any are found to be low the necessary corrective measures should be applied. Before making any readjustments it is suggested that the position of the adjustment screw heads be noticed so that if desired the original adjustment could be duplicated.

With the receiver completely connected, turn on the proper control for full volume by means of the Tone Color switch and the Volume Control rheostat. The wave changing mechanism should be set for high-wave reception. The thumb nuts controlling the coupling chains on the dial should next be loosened so that all dials tune independently. The dials should be rotated to the following positions:

Left hand dial controlling the frequency of the first or antenna tuned circuit is set on 100. Master or center dial controlling the input circuit of the second radio amplifier is set on 40. With a small bakelite wrench (with a slot cut to fit the hexagon lock nut on the balancing condenser screws) loosen the nut on balancing condenser C6, meanwhile rotating the master dial between 30 and 50 until a click is heard. Now tighten the adjustment until the click disappears and, finally tightening the balancing condenser, screw about a quarter turn beyond. This should be followed by setting all dials at 40, and then rotating the left hand dial between 30 and 50 observing the same clicking noise and making similar adjustments to balancing condenser C5 as described for condenser C6. After this procedure is completed the dials should be rotated until all the tuned circuit are in resonance for the reception of signals on various wavelengths. If there is any tendency for the circuits to oscillate on the high wavelengths, screw in balancing condenser C5 slightly further, whereas, if oscillation is experienced on the lower wavelengths, screw in balancing condenser C6. If the first attempt to neutralize the tube capacities is unsuccessful this procedure should be repeated.

The compensating condenser shown in the wiring diagram of Figure 3, shunted across tuning condenser C3, may be adjusted if found necessary in order to exactly synchronize the second and third tuned circuits controlled by tuning condensers C2 and C3. The correct adjustment will make the right-hand and middle dials tune to identical numbers for a given station. No adjustment of the compensating condenser should be made until balancing condenser C5 and C6 have been finally adjusted, and the station received for this test should be one which tunes in on the dials between 10 and 20 degrees. If the righthand dial reading is higher than the middle dial screw in compensating condenser adjustment and, in the contrary, if the dial reading is too low screw out on the adjustment. Adjustments of this condenser will be practically unnoticed on the higher readings of the dials.

Electrical Testing: The electrical testing for the continuity of a circuit is absolutely essential at times when it becomes necessary to quickly determine the nature of certain troubles that are possibly interfering with

the functioning of the receiver. Whenever difficulty is experienced and it appears to be located internally in the receiver, and not in accessories such as tubes, batteries or loudspeaker, etc., the explanation incorporated in the following paragraphs will be of material assistance in testing parts and wiring of the circuits.

A complete test of a receiver can only be effected when the chassis is removed from the cabinet. The chassis mounting board is held securely in place in the cabinet by three screws on each side. These screws and the cover support screw must be removed before the chassis can be removed. The instrument should be raised evenly in order to allow the panel to slide up through the supporting grooves in the sides of the cabinet. If this is not carefully done binding and strain on the grooves will result.

The most practical equipment for continuity testing purposes consists of a d-c voltmeter with a scale reading from 0-100 volts, and 45 to 90 volts obtained from one or two "B" batteries connected in series, as shown by the sketch in Figure 9. The cords used for testing should be at least three feet long for convenience. Test lead ends should be covered with spaghetti insulation to eliminate leakage through the hands. Reference to the electrical test layout chart in Figure 8 shows the location of all terminal lug connections with identifying numbers. The various tests specified in the "Test Chart Instructions" must be carefully made by touching the test points to the various lugs or connections on the set corresponding to the numbers on the chart. If defective parts are located it is obvious that the remedy consists in a replacement, using a perfect part of similar type. Adjustments, short circuits, and open circuits in wiring may be corrected easily after having found the seat of the difficulty.

Notice that all of the electrical tests set forth in the chart of instructions are numbered in the first column. The numbers in the second and third columns refer to the numbered lugs or connections on the test chart layout to which the test points should be touched at various places when the receiver is being tested. The results to be expected as shown by the deflection of the meter vane are listed in the fourth column.

If the incorrect effect is observed by the meter reading the difficulties that are likely to be responsible therefore are indicated in the last column headed "Remarks". Practically every ordinary trouble that might arise in the set can be expeditiously located in some one of the tests suggested. Tests should be carefully made and the numbers checked to avoid incorrect indications. A few examples will be helpful in illustrating the use of the test chart: Test No. 2 should be used in order to ascertain whether the primary winding of the second radio-frequency transformer is in perfect condition. This test is made by placing one test point on location 1, which is the shell of the fuse lamp socket, and the other test point to location 33 which is the stationary plate of the balancing condenser (marked C5 in the wiring diagram of Figure 3) mounted on the side of the center variable tuning condenser as shown in Figure 10. According to the chart the meter needle should show a deflection indicating a closed circuit. With the test point kept on location 1 the other test point is moved from location 33 to location 11 which is the plate contact terminal of the second radio-frequency

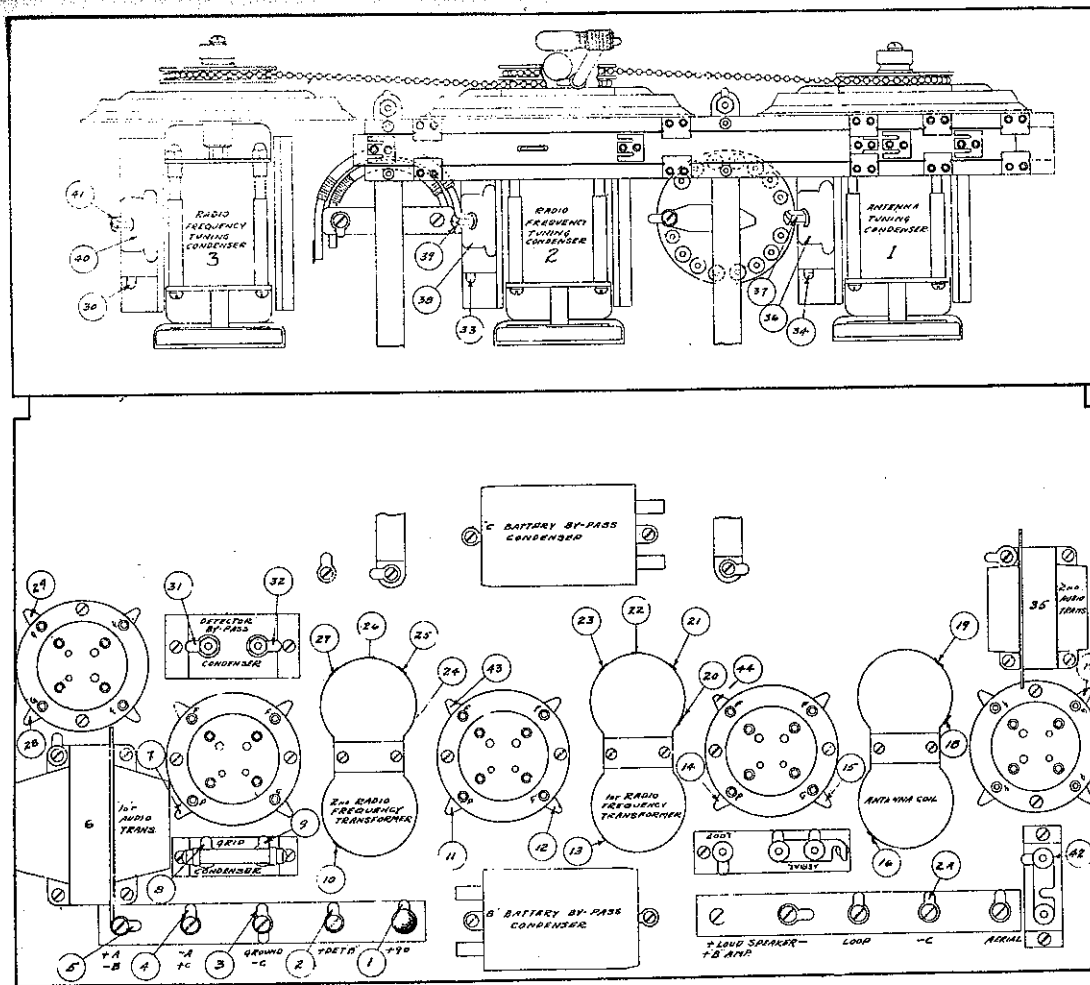


Figure 8

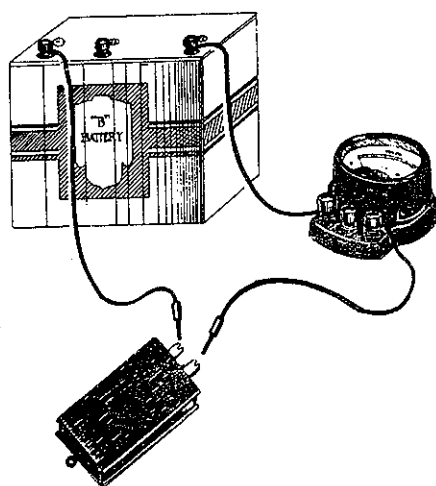
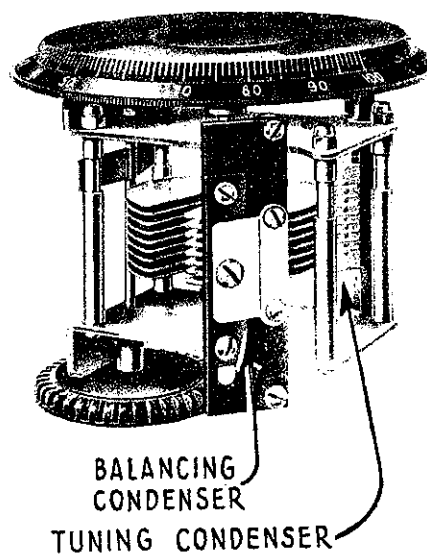


Figure 9



BALANCING
CONDENSER
TUNING CONDENSER

Figure 10

tube socket. A deflection of the needle will again indicate a normal condition showing a closed circuit. Each test has indicated that both halves of the primary winding are in perfect condition.

Test Number	Location Numbers	Correct Indications		Remarks
		Meter Reading	Circuit Condition	
1	1- 34 and 14	Deflection	Closed	<u>PLATE CIRCUITS</u> No reading signifies open Primary in First Radio Frequency Transformer.
2	1- 33 and 11	"	"	No reading - open Primary of Second Radio Frequency Transformer.
3	2- 7	"	"	No reading - open Primary of First Radio Frequency Transformer.
<u>GRID CIRCUITS</u>				
Note: Before testing grid circuits set all tuning condenser dials at "0". If of condenser plates are shorted this will not affect other tests.				
4	3- 15	"	"	No reading - Loop Link Switch open or not making contact.
5	3- 12	"	"	No reading - Open Secondary First Radio Frequency Transformer.
6	3- 42	"	"	No reading - Open Antenna Coil.
7	3- 28	"	"	No reading - Open Secondary First Audio Frequency Transformer.

8	3- 17	Deflection	Closed	No reading - Open Secondary Second Audio Frequency Transformer.
9	1- 3	No Deflection	Open	If reading is obtained it indicates Primary First Radio Frequency, is shorted to Secondary, or No. 1 or No. 2 Balancing Condenser (marked C5 or C6 in wiring diagram). Or, Primary of Second Audio Trans. grounded, or "B" Battery By-Pass Condenser shorted.
10	2- 3	"	"	If reading is obtained it shows Primary of First Audio Freq. Transformer is grounded, or Primary and Secondary shorted.
11	1- 2A	"	"	If reading is obtained Primary and Secondary of Second Audio Freq. Trans. shorted.
12	1- 5	"	"	If reading is obtained it shows Primary of Second Radio Freq. Trans. is shorted to Secondary.
13	1- 8	"	"	If reading is obtained it shows Second Radio Freq. Trans. Secondary is shorted to Primary.
14	3- 6 and 35	Deflection	Closed	Shows cores of Audio Trans. are grounded.
<u>VOLUME CONTROL</u> <u>RHEOSTAT</u>				
15	5- 8 and 43 and 44	"	"	Turn Volume Control on full, if meter flickers it indicates

contact arms not making good electrical contact with resistance wire.

CONDENSERS

16	31- 32	No Deflection	Open	If reading is obtained it shows Detector By-Pass condenser shorted.
17	4- 3	"	"	If reading is obtained it shows shorted "C" Battery By-Pass Condenser.
18	1- 3	"	"	If reading is obtained it shows shorted "B" Battery By-Pass Condenser.
19	8- 9	"	"	If reading is obtained it shows shorted Grid Condenser. The leak should be removed when making this test.
20	30- 40	Deflection	Closed	If no reading is obtained it shows third Balancing Condenser (marked Compensating Condenser on wiring diagram) is not in circuit or Second Radio Freq. Trans. Secondary is open. Note: Test "B" Battery By-Pass condenser for grounded case by touching one test point to case and other to location 1.
21	3- 37 and 39	No Deflection	Open	If reading is obtained it shows that Balancing Screw is shorting Balancing Condenser.
22	3- 36 and 38	Deflection	Closed	A deflection shows that one side of Balancing Condenser is connected in circuit correctly.

NOTE: When testing 1 MFD. by-pass Condensers the meter should show a very small momentary deflection; i.e., one which will fall quickly to zero when test points are first applied to the condenser terminals. This movement of the needle does not indicate a short circuit, but merely registers the small charging current flowing to the condenser. A second deflection can be obtained by reversing the test leads. Figure 9 shows a by-pass condenser and a test circuit.

TONE COLOR CONTROL

23 3- 17 No Deflection Open

Moving tone-color switch should show no deflection. If reading, it indicates shorted Tone-Color. This test applies only to certain sets equipped with the No. 289 Color-Tone Condenser Switch.

24

Testing Pilot Lamp Circuit, test points should be touched to panel supporting brackets. If reading is obtained with lamp removed it indicates a shorted Pilot Lamp socket.

25

Testing "B" Battery Fuse Lamp. Touch one test point to location 1 and other to binding post underneath. This should show closed, but if no reading is observed it indicates Fuse Lamp is either burnt out or not firmly screwed down in the socket. The protective fuse lamp is a small 1.25 or 1.5 volt flash light bulb.

26

Remove Fuse Lamp. Same test should show no circuit. If reading is obtained it indicates socket is leaking or shorted, due to fibre washer in socket becoming wet or slipping out of place.

27	3- 2A	No Deflection	Open	If meter reads it shows shorted "C" battery wiring.
28	2A- 4 and 5	"	"	If meter reads it indicates a short to negative "A" and positive "A" respectively.
29	2A- Loudspeaker Negative	"	"	If meter reads it indicates grid short to plate of Second Audio Socket.

TESTING RADIO AND AUDIO FREQUENCY TRANSFORMERS

Although the tests already mentioned will isolate any defects in the Radio Frequency and Audio Transformers, the following tests may be employed if desired to test these transformers separately.

30	13- 20	Deflection	Closed	No reading indicates open in Secondary of First Radio Freq. Trans.
31	21- 23	"	"	No reading indicates open in Primary of First Radio Freq. Trans.
32	23- 22	"	"	
33	22- 21	"	"	
34	10- 24	"	"	No reading indicates open in secondary of Second Radio Freq. Trans.
35	27- 26	"	"	No reading indicates open in Primary of Second Radio Freq. Trans.
36	26- 25	"	"	
37	27- 25	"	"	
38	16- 18	"	"	No reading indicates Antenna Coil open.

If it is desired to distinguish the windings of an Audio Transformer, it should be held so that you are facing the rivet heads, and the fibre terminal strips are nearest to you. In this position the Primary winding is on the Left and the Secondary on the Right.

On test, the Primary winding of either type Audio Transformer should show slightly less than full reading.

On test, the Secondary winding of either type Audio Transformer should show one-half to one-third value of full reading depending upon the sensitivity of the meter employed in these tests.

The fuse lamp (flash light bulb) is intended to serve a purpose which is identical to a wire fuse. That is, if a short circuit occurs, it will burn out the filament thus opening the electrical circuit, which provides protection against further damage until the cause of the trouble has been located and corrected. It is not intended that the small lamp should light at any time, and as a matter of fact if it did light up the filament would burn out almost immediately because it would be subjected to excessive voltage - the lamp would receive the same "B" voltage used to energize the plates of the radio amplifier tubes.

The installation of the battery connecting cable will now receive consideration. A reproduction of the wiring to the antenna, ground, loudspeaker, "A", "B", and "C" batteries is shown in Figure 11.

A battery cable should be procured having a sufficient number of leads to make every necessary connection to "A", "B" and "C" batteries. In most cables two leads are supplied, these being made up from larger sized stranded wire than other leads. The two heavier wires are proportioned to carry a heavy current load and are to be used expressly for the filament supply which is obtained from the "A" storage battery. Each lead is covered with a distinctive colored cotton braid which simplifies making connections between the terminal posts on the rear of the chassis and the batteries. A safe procedure is to attach all connections to the receiver first and by selection of a particular tracer color lead, one that has already been

attached to a terminal post, it will suggest the correct lead in the other end of the cable to be used in making a corresponding connection to a battery terminal.

If a battery cable is not procurable a sufficient number of connecting leads of proper length could be used. For this purpose a rubber covered No. 18 B & S gauge stranded wire will be found satisfactory. The ends of the wire should be pared about a distance of one-half to three quarters of an inch and the strands carefully twisted to form a neat solid end. When using wires which cannot be identified by a tracer color scheme, it is the safest method to connect up only one wire at a time, one end to the receiver terminal post and the other to the proper terminal on the battery.

GREBE ALTERNATING CURRENT RECEIVER

Radio receiving sets are grouped into two general classes, namely: (1) Sets designed for operation on batteries, and (2) for complete operation on alternating current supplied from the house lighting system. The standard term "socket-power" is used to describe the unit or device which supplies "A", "B" and "C" voltages from the lighting circuit by the throwing of a switch.

The modern alternating current receiver is self-contained, the receiver proper consisting of the radio-frequency amplifiers with tuning system, the detector, and the audio amplifying system being mounted on one metal base or chassis with the power unit, which is composed of a power transformer, a single tube full-wave rectifier, a filter system and a set of resistances. The resistance units are known as the voltage divider system because from them the various plate circuits and certain grid circuits of the receiving tubes are supplied with the proper voltages for efficient performance. The voltages required to energize the filaments are obtained from individual windings on the power transformer.

The Grebe "A.C. Six" described in the following paragraphs is a representative type of alternating current receiver. It incorporates certain features which are similar to the standard Syncrophase receiver, particularly in the tuned radio frequency circuits. The complete schematic diagram of the receiver and the power unit included is shown in Figure 12.

Alternating current tubes of the 226 or 326 type are used throughout this receiver, with the exception of the final stage of audio amplification, called the audio output and the detector tube. A regular type vacuum tube of the 171 type, known as a power tube, is used in the audio output stage because it delivers a large amount of signal power, free from distortion, to the loudspeaker when worked with correct amounts of plate and grid voltages. This tube is not a special a-c tube, it is suitable for operation in the output of either a d-c or a-c receiver.

The 226 or 326 type a-c tubes used for the three radio frequency stages and first audio stage are constructed with a special filament wire of large diameter, its size being considerably greater than the wire used in the regular d-c type vacuum tube. A large sized filament wire is quite necessary when the wire is heated by alternating current. It can be recalled

that during certain periods of an alternating current cycle the current falls to zero value; this decrease in current strength would tend to allow the wire to cool off slightly. A large wire, however, receives sufficient heat from the average current intensity throughout a cycle to maintain a practically uniform temperature. Hence, the filament emits electrons in practically unvarying quantities for attraction by the plate. Remember, if the filament did not retain its heat there would be a periodic fluctuation in temperature which would be evidenced by a 60-cycle hum reproduced in the loudspeaker.

The UY-227 or C-327 a-c. heater cathode tube is used for the detector. This tube utilizes an independent element consisting of an oxide coated cylinder mounted over the filament wire for the purpose of allowing the heat produced by the filament to be communicated to this cylinder. When heated to the correct temperature the oxide coating on the cylinder becomes the source of electrons in the tube, and is known as the cathode. In the usual type vacuum tube the hot filament is the cathode. For convenience in identifying the elements in the 227 or 327 tube we refer to the filament as the "heater" and the electron emitting cylinder as the "cathode". The regular spiral wound grid surrounds the cathode while the plate encloses all of the other elements in the tube. The theoretical action within the heater-cathode type tube does not differ from the regular type; the signal voltages applied to the grid serve to control the amount of electrons which actually reach the positive charged plate. There is, however, a slight modification in the wiring from the socket of this tube to the receiving circuit because the filament, heated with alternating current, does not actually form part of the radio circuit proper. This construction requires that a fixed potential of suitable value be maintained between the cathode and heater (the filament) operating the heater with a negative potential with regard to the cathode prevents the heater from exercising an attraction for electrons emitted by the cathode. The stream of electrons normally travel within the tube from cathode to plate or anode, and therefore any electron energy diverted from this path, for instance toward the heater or filament, would simply destroy the functioning of the tube.

A convenient switch permits the receiver to be used with a long or short antenna. This switch operates to place a small condenser of 0.00025 mfd. capacity in series with the antenna circuit or to remove it from the circuit. An explanation of how a series condenser will alter the natural wavelength of an antenna circuit is included in the description dealing with the Synchrophase receiver. The diagram in Figure 12 shows that the antenna is attached directly to the primary coil of the first radio frequency transformer when using a short antenna.

Various lengths of antennas noticeably effect the constants of the first tuned circuit. The effect is known as the detuning effect, and would, if allowed to exist, disturb the synchronism of the remaining tuned circuits. It is therefore quite necessary to provide some compensating adjustment which may be easily set after the receiver is connected to a particular antenna. This regulation of the first tuned stage is accomplished in a practical manner through a variable inductance inserted in series with the secondary coil. The compensating coil is drawn in the diagram at right angles to

the secondary coil, this being done to indicate that these coils are mounted mechanically in positions which prevent the establishing of mutual inductance between them. That is to say, there is no magnetic coupling existing between them. The compensating inductance simply permits the inductance of the secondary circuit to be changed according to the requirements and after once being adjusted it needs no further consideration unless the dimensions of the antenna are altered.

The correct adjustment of the compensating inductance will permit the accurate operation of the four ganged condensers, which allows single-dial tuning control. The capacities of these tuning condensers, marked C1, C2, C3, and C4 on the diagram, are varied simultaneously when manipulating the one dial. The condensers have plates shaped so that the broadcasting channels at the lower wavelengths are spread across the dial at sufficient intervals to provide easy selection of a desired station without sacrificing selectivity. The radio frequency stages employ transformers of the binocular type. This results in the elimination of external magnetic fields in the spaces between the coils, a feature which stabilizes these circuits and has already been dealt with in the Synchrophase receiver.

The volume control used in this receiver consists of a variable resistance of 2500 ohms connected in shunt to the primary winding of the fourth radio frequency transformer. The manipulation of this control regulates the amount of signal voltage generated across the primary or plate coil. This control of signal energy in the primary of the transformer in turn governs the voltage induced into the secondary and finally the amount of signal voltage admitted to the detector grid. It is to be observed that this method of regulating the output of the set does not disturb the normal voltages applied to the filaments, and consequently, there is no unbalancing of the filament circuit which might cause an interfering "hum" to be produced.

A "local" and "distance" switch controls a resistance of 170 ohms shunted across the plate coil of the second radio frequency transformer. The purpose of this arrangement is to provide maximum tone quality when receiving local broadcast programs. With the resistance placed in the circuit by means of the switch the tuning is slightly broadened resulting in a greater sideband response. Stating this in another way, it means that the tuning qualities of the circuit will not act to cut off or choke out frequencies which lie outside a specified band and which carry certain harmonics of the voice or music that give the reproduction the naturalness of the original sounds directed toward the microphone of the broadcast transmitter. When this fixed resistance is cut out, the circuit is in a condition for sharper tuning. Although some of the side band frequencies, just referred to as harmonics, may be cut off due to sharper tuning and hence cannot be reproduced in the loudspeaker, nevertheless there is a noticeable gain in the degree of selectivity and sensitivity of the receiver which is especially desirable when tuning in a distant station through local interference.

Let us now consider the electrical features of the receiver under discussion. The power unit is designed for operation on 110 to 120 volts, 60 cycle alternating current, and furnishes complete filament, plate and grid voltages to the set. This unit is divided into two separate power transformers,

both of which take power from the a-c house lighting system. One transformer, marked T-1, operating in conjunction with a full-wave rectifier tube, converts the alternating current into direct current of sufficient voltage for energizing the plates of the receiving tubes. The second transformer, T-2, supplies alternating voltages to the various "A" or filament circuits of which there are three. The number of turns of wire used on the primary and three secondary windings of T-2 are calculated to lower or "step-down" the 110 or 120 volts to the necessary values as indicated on the diagram.

One secondary of T-2 supplies 1.5 volts to each of the four 226 or 326 type tubes, the filaments of these tubes being connected in parallel and shunted by a 27 ohm resistance which is mid-tapped and grounded for hum balance. The movable contact arm provided on this resistance permits the electrical balance of the filament circuit to be easily obtained. Another separate secondary of power transformer T₂ supplies approximately 2.25 volts to the detector tube filament. The filament of this tube, type 227 or 327, is technically known as the heater as previously mentioned. A potentiometer, marked R-1, shunted across this heater, has its mid-tap fixed and attached to the negative 40 volt lead supplying the grid biasing voltage to the audio output tube as shown in the diagram. This tube's filament obtains the requisite operating voltage from the secondary of T-2. As stated heretofore, the tube employed in the output is a 171 or 371 type, classified as a power tube, the filament consuming .25 amperes at a terminal e.m.f. of 5 volts. The current supply to this tube is shunted by the potentiometer R-2, with its mid-point grounded for hum balance.

It is a good point to remember that if at any time a balancing potentiometer accidentally burns out or opens, or should either side of the filament circuits from the transformer windings to the tube sockets be grounded, a disagreeable 60 cycle hum will be heard in the loudspeaker. A hum resulting from this cause cannot be reduced to a minimum or suppressed by means of the adjustments provided. The remedy for this condition is to either replace the defective part or remove the ground as the case may be.

We can now see from the foregoing explanations that the power transformer T-2, consisting of a primary and three secondary windings, is utilized solely to supply alternating current to heat the filaments of the three radio-frequency and first audio tubes, the detector tube heater, and the audio power tube.

The purpose of power transformer T-1 is to "step-up" the 110 volts a.c. to a higher voltage, alternating current, of the required value for plate supply. The transformer is designed to deliver an e.m.f. of several hundred volts at the secondary terminals of S-2 in order to allow for losses to be encountered in the rectifying and filtering systems which are to follow.

It is necessary to supply direct current to the plates of the receiving tubes. This is accomplished by connecting the filament type rectifying tube to the output of the transformer in the manner shown in the diagram. The operation of this device is as follows. The tube consists of two filaments and two plates, each plate being attached to opposite ends of the transformer secondary. Filament current for the rectifier tube is obtained

from a low voltage secondary winding marked S-1. Notice that a mid-tap taken on this coil is the positive side of the output of the rectifier and a mid-tap on the plate coil S-2 is the negative side. Now, by the action of the tube the alternating current passing to it from S-2 will be changed into a pulsating direct current; that is, a current which flows in one direction only, but rises and falls in strength between zero and maximum values. The rectification process is based upon the peculiar action going on in all vacuum tubes operated with a hot filament; the electrons emitted by the filament can only reach the plate when the latter is charged with a positive electric potential. Electrons cannot pass from plate to filament through the vacuous space within because the plate is a comparatively cold element and cannot give off electrons. The alternating voltage across S-2 is delivered to the plates of the rectifier tube which causes each plate to become excited alternately by positive and negative charges. It is, however, only during those periods when either plate is charged with a positive potential that the electron stream, which constitutes current flow, passes between the filament and plate. Thus, it is seen readily that current will flow freely through the tube in one direction, but it acts practically as an insulator for current in the opposite direction. Since two plates are employed, one will be active during the positive half-cycles (alternations) and the other idle during negative half cycles. It then follows that current passes through one or the other plates each half-cycle, or 120 pulsations of uni-directional current are produced by the rectifier tube. It is for this reason that a tube, with two plates and utilizing both halves of the a-c. cycle, is known as a full-wave rectifier.

The pulsating direct current provided by the rectifier tube is not suitable for energizing the plates; it requires a steady direct current to give a positive potential of unvarying value, so it becomes necessary to "filter" or smooth out this current to provide a non-fluctuating flow. This is done through a single section "brute force" filter consisting of an iron core choke coil and two high voltage condensers of 4 and 5 mfd.

The output of the filter furnishes a steady direct current of high voltage. To complete the power unit it simply remains to distribute this current to the various plate circuits of the receiving tubes at specified voltages. In order to accomplish this efficiently a set of resistances, called a voltage divider, and by-pass condensers, are connected across the output of the filter between points A and B. A good understanding of the circuit we are describing will be had by referring to the schematic diagram where it will be seen that the voltage divider supplies the correct voltages to the radio-frequency, detector, and audio tube plates and to the grids of all the tubes with the exception of the detector. The grid of the detector is returned to the ground.

The voltage divider resistance consists of six sections as follows. The first section marked 750 ohms reduces the output voltage of the filter to 180 volts required by the power amplifier tube. The next resistance, rated at 2800 ohms, will cause a loss in voltage or voltage-drop of 80 volts which reduces the voltage available at this point to 100 volts for the first audio and three radio-frequency tube plates. The resistance section of 5900 ohms lowers the voltage to 45 volts for the detector plate supply. A voltage drop of 45 volts, provided by the 6300 ohm resistance, leads to

the common connection -B +C of the receiving circuit proper. The next step is the supplying of the biasing voltages to the grids of those tubes which depend upon specified negative voltages for efficient operation. A 95 ohm resistance section connected in series with the resistances already described, supplies a 4.5 volts negative "C" bias to the grids of the three radio-frequency and first audio tube. An additional voltage drop of 40 volts obtained across the resistance section of 695 ohms is applied to the grid of the output audio tube. These values will vary slightly with fluctuations in line voltages from the house lighting mains, which, however, should have no noticeable effect on the efficiency of the receiver within the specified 110 to 120 operating range.

Whenever possible a good a-c. voltmeter should be used to measure the house lighting line voltage so that the tubes in the receiver will not be over-loaded with excess voltage. The two-position switch included in the primaries of transformers T-1 and T-2 should be placed in the 120-v position where the a-c. line voltage is higher than 115 volts, and in the 110-v position where the line voltage is less than 115 volts. If it is not known that the line voltage varies over a range of voltage at different times of the day and night, or from day to day, reaching values over 115 volts, this switch should be kept in the 120 volt-position. If you are in doubt at any time as to the normal line voltage supplied to an electrically operated receiver of any type, be sure to place a switch of this kind, when one is provided, in the high voltage (120-v) position. The schematic diagram clearly shows that fewer turns of wire are utilized on the primary when the line voltage switch is in the 110-v position; this reduction in the primary turns used increases the step-up ratio of the transformer.

Some form of loudspeaker coupling should be placed between the 171-power tube and the loudspeaker in order to prevent the high plate current of approximately 20 milliamperes from passing through the windings. The speaker unit can be isolated from the plate circuit and thus avoid the possibility of burn-out by employing an output transformer with a ratio of one to one (1:1), or any choke coil and condenser combination of correct electrical values for use with the 171 or 371 type tube. The transformer method of coupling indicated in dotted lines on the diagram serves to illustrate the idea of one form of coupling arrangement.

EXAMINATION - LESSON 50

1. What effect upon the tuning qualities of the receiver is noticed when using a short or long antenna?
2. Name the piece of apparatus that is automatically added to the antenna system when a long antenna is employed and connected to the "Long Antenna" terminal post of the receiver. Why is this particular part not required when a short antenna is erected?
3. Explain how the control of volume is accomplished in both the battery operated and electrically operated receivers.

4. Why are the link chains, connecting the tuning condensers of the battery operated receiver, designed with a locking device that may be unlocked at the will of the operator thereby permitting the dials to be rotated independently?
5. What is the difference between the "heater-cathod" type and "filament" type tube?
6. (a) How are the grid negative biases obtained for the a-c tubes?
(b) From what source are the plate voltages obtained, and (c) Filament voltages?
7. It is suggested in this lesson that a coupling device of some kind be used between the plate or output of the last audio (power) tube and the loudspeaker of the a-c. set. State briefly the reason for this suggestion.
8. (a) Explain the purpose of the binocular type coil. (b) What is the general construction and method of winding a coil of this kind?
9. Draw a simple sketch of three binocular type transformers and show by means of dotted lines and arrows the relation of the magnetic fields produced by each coil.
10. (a) What effect is produced upon the tuned circuits of the battery operated receiver when the number of turns used on the binocular coils is reduced? (b) When should the switching arrangement which controls this feature be put into practical use?